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Effects of Respiratory Muscle and Endurance Training using an Individualized Training Device on Pulmonary Function and Exercise Capacity in Stroke Patients

Authors' Contribution:
Study Design A
Data Collection B
Statistical Analysis C
Data Interpretation D
Manuscript Preparation E
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Background: Because respiratory muscle function plays a strong role in exercise capacity and cardiopulmonary response to exercise, systematic training and measurement of respiratory muscle function should be considered in stroke patients. The purpose of this study was to determine whether an individualized respiratory muscle training device combined with conventional physical therapy exercise can improve the pulmonary function and exercise capacity of stroke patients.

Material/Methods: Twenty stroke patients were randomly assigned to an exercise group (n=10) or a control group (n=10). Over 4 weeks, each group participated in exercise training interventions 3 times per week. In each session, the control group received basic exercise treatments for 30 min, followed by an automated full-body workout for 20 min. The exercise group performed the same exercise regimen as the control group, as well as an additional respiratory muscle training regimen using a respiratory exercise device for 20 min.

Results: Pulmonary function of forced vital capacity (FVC), forced expiratory volume at 1 s (FEV1), FEV1/FVC, and peak expiratory flow (PEF) and exercise capacity of a 6-min walking test and Shortness of Breath Modified Borg Dyspnea Scale (SBMBDS) scores were assessed before and after the training. A significant intergroup difference was observed in the FVC, FEV1, PEF, 6MWT, and SBMBDS scores ($p<0.05$).

Conclusions: These findings suggest that exercise of the respiratory muscles using an individualized respiratory device had a positive effect on pulmonary function and exercise capacity and may be used for breathing rehabilitation in stroke patients.

MeSH Keywords: **Breathing Exercises • Respiratory Function Tests • Respiratory Muscles • Stroke**

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Background

Stroke is one of the most common causes of long-term disability worldwide, and stroke patients need assistance with activities of daily living. Therefore functional recover after stroke is a high priority for healthcare [1,2]. Generally, respiratory muscle weakness is attributed to the impairment of the muscles involved in respiration, induced by central nervous system (CNS) lesions [3].

The cardiopulmonary functions of patients with hemiplegia caused by stroke diminish due to the decreased expansion of the damaged hemi-thorax and deterioration of the respiratory muscles. Furthermore, the common symptoms observed in stroke patients, including ankylosis and limited use of muscular movement, result in a decrease in cardiorespiratory control and the capacity of oxygen-transferring systems due to a combined lack of oxygen and increased metabolic demands [4]. Upon paralysis of the diaphragm and respiratory muscles following stroke, the thorax cannot sufficiently expand. Continuation of this condition can lead to shortening of the thoracic cells and muscle fibrosis. Consequently, the level of thoracic expansion may be reduced during breathing [5]. Therefore, deterioration of cardiopulmonary function is one of the most significant factors associated with stroke patients.

Respiration exchanges air in blood around the lungs, which is the core of the ventilation system. It is controlled by the respiratory muscles and neurological regulation [6]. Patients with stroke may show a deterioration of respiratory function that requires intensive rehabilitation treatment. During aerobic exercise, which requires endurance, patients readily feel fatigue. This may lead to difficulty in ensuring consistent rehabilitation treatment, thereby reducing the patient's ability to perform daily activities and decreasing their chances of making a functionally sufficient recovery and leading an independent life [7]. Resistance exercise is a promising physiotherapeutic intervention for patients with stroke. Previous studies have conducted muscle-strengthening and aerobic exercises for deteriorated respiratory muscles by controlling the compensatory effects. The data from these studies have indicated that the strength of respiratory muscles and pulmonary function may significantly increase as a result of these exercises [8,9]. In addition to problems in exercise capacity, patients with stroke usually have deteriorated cardiopulmonary function and a reduced ability to perform aerobic exercise [10]. It has been reported that the performance of aerobic exercises in patients with stroke, in order to improve this condition, results in a decrease of cardiovascular risk factors, an improvement in cardiopulmonary function, functional improvement of everyday life activities, and an enhancement of motor sensory functions and walking ability [11,12].

Patients diagnosed with stroke spend 20% of the time they are awake on recovering their deteriorated physical function. Of this 20%, 4% is used for performing rehabilitation exercises for the damaged upper and lower body and 16% is used for performing tasks such as walking, sitting down, standing up, balancing while sitting or standing up, and using the damaged upper body [13]. A general stroke rehabilitation program, which focuses only on physical and functional recovery, may not sufficiently enhance the patient's cardiopulmonary function [10,13]. Therefore, a rehabilitation program integrated with breathing-related intervention will be effective in improving the ability to perform functional activities, including walking [14,15], in patients with stroke.

A medical device for strengthening the respiratory muscles has been used in diverse patient groups, including those with chronic obstructive pulmonary disease (COPD), asthma, spinal damage, muscle disease, Parkinson disease, and stroke. Treatment devices for exhalation include high-frequency chest wall oscillation, flutter, and exhalation positive-pressure mask [16]. Treatment devices used for strengthening the inspiratory muscles include a resistance-breathing device and a threshold-loading device. The RESPIFIT S (Biegler GmbH, Mauerbach, Austria) is an individualized respiratory muscle training device used to strengthen the inspiratory muscles. The use of this training device for 1 year in a cohort of 42 patients with COPD improved respiratory muscle strength and exercise capacity, reduced dyspnea and days of hospitalization, and improved overall quality of everyday life [17]. The device was used for 12 weeks in a study of 10 patients with Parkinson disease, showing improvement in respiratory muscle strength, increased endurance, and enhancement of dyspnea and cognitive ability [18]. Although exercise treatment along with use of breathing exercise equipment has been shown to be diversely effective, there has been little research on use of individualized respiratory muscles and endurance training equipment combined with conventional physical therapy exercise for stroke patients. In addition, little research has been conducted to investigate whether the use of respiratory muscles and endurance training positively affect pulmonary function and whether this is associated with improved exercise capacity.

The present study aimed to determine if pulmonary function and exercise capacity in patients with chronic stroke were changed following respiratory muscle and endurance training using an individualized respiratory muscle training device combined with conventional physical therapy exercise.

Material and Methods

Subjects

Thirty patients with stroke were informed of the goals and overall protocol of this study. Of these patients, 20 met the

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Table 1. General characteristics of subjects.

	Exercise group (n=10)	Control group (n=10)	p
	Mean ±SD	Mean ±SD	
Age (years)	54.10±11.69	53.90±5.82	.96
Weight (kg)	64.40±10.12	59.20±6.82	.20
Height (cm)	167.30±9.51	163.00±6.60	.26
Time since stroke (month)	13.76±4.02	13.50±2.76	.281
Paretic side (right/left)	5/5	7/3	

selection criteria and were assigned randomly to either the exercise (n=10) or control group (n=10) by having each of the subjects take out 1 card from a box containing 2 types of cards representing both study groups. We included patients who: had experienced the first episode of unilateral stroke with hemiparesis during the previous 6 months and were capable of comprehending commands and walking for at least 6 min with or without the use of an assistive device, had no previous history of cardiovascular or respiratory problems, were receiving no medications that would influence the metabolic or cardiorespiratory responses to exercise, had no history of regular exercise training or sports activity to strengthen ventilator muscles, and had no bone deformities of the chest or spine. The general characteristics of the subjects are shown in Table 1. All protocols and procedures were approved by the Institutional Review Board of Sahmyook University (Seoul, South Korea) and all the subjects signed a statement of informed consent.

Intervention

Twenty patients with chronic stroke were randomly assigned to an exercise (n=10) or control group (n=10). Over 4 weeks, each group participated in exercise training 3 times a week.

Control group

The control group received conventional exercise treatments for 30 min (including joint mobility, eccentric contraction, muscle strengthening, and walking exercise), followed by a 10-min rest. The patients then exercised using an automated full-body workout machine (Super Dynamic, Korea) for 20 min.

Exercise group

The exercise group received the same conventional exercise treatment as the control group for 30 min, followed by 10-min rest. The patients then exercised using an automated full-body workout machine (Super Dynamic, Korea) for 20 min, followed by another 10-min rest. Finally, the patients had individualized respiratory training for 20 min.

This study used the RESPIFIT S® as a respiratory training device for strengthening the respiratory muscles and endurance. The device is composed of the main body into which a program card is inserted, a handle mouthpiece to adjust the exhalation and inhalation volumes and modules, a program card adjusted by the breathing capacity of each patient, and a transparent tube that connects the main body to the mouthpiece.

The exercise was conducted with the patients biting the handle mouthpiece while sitting and looking at the main body of the RESPIFIT S. The therapist inserted a program card into the device, which was individually adjusted and set to the breathing capacity of each patient. The therapist operated the main body to initiate the respiratory muscle training or endurance training, which was displayed like a game on the main screen. At the midpoint of the breathing exercises, if the patient felt fatigued or dizzy, a rest was permitted before resuming the remainder of the exercise. Prior to the test, the therapist trained the patients on 2 or 3 occasions to accustom them to the breathing exercise.

Outcome measures

Measurement of lung capacity

Pulmonary function was measured using a One Flow FVC Spirometer (Clement Clarke, UK) while sitting. The study measured forced vital capacity (FVC), forced expiratory volume at 1 s (FEV1), and the FEV1/FVC ratio, to determine signs of obstructive or limited pulmonary disease. The peak expiratory flow (PEF) was measured to assess resistance of the respiratory tract.

Six-min walk test (6MWT)

The 6MWT was used to measure the distance moved during 6 min [19]. The 6MWT was conducted in an indoor setting, with a track marked with tapes at 1-m intervals. When the patient started to walk, the measurer started to time the walk using a stopwatch, which was set to ring after 6 min. The 6MWT is

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Table 2. Comparison of outcome variables in pulmonary function.

		Pre	Post	Post-Pre	P
FVC(l)	Exercise group	2.90±1.12	3.99±1.19	1.09±0.87	.003*
	Control group	2.67±0.68	2.90±0.81	0.23±0.44	.137
				P=.015*	
FEV1(l)	Exercise group	2.01±0.71	2.64±0.62	0.63±0.57	.007*
	Control group	2.33±0.57	2.37±0.50	0.04±0.27	.667
				p=.012*	
FEV1/FVC(%)	Exercise group	73.80±20.31	70.40±22.32	3.40±17.62	.557
	Control group	87.70±9.45	83.40±10.30	4.30±10.37	.222
				p=.891	
PEF(l/s)	Exercise group	264.00±97.86	358.00±98.607	94.00±80.61	.005*
	Control group	359.00±106.06	367.50±106.88	8.50±51.74	.616
				p=.011*	

$p<.05$.

a highly reliable method of evaluating muscle endurance and functional walking ability of patients with stroke (r=0.91) [20].

Shortness of Breath Modified Borg Dyspnea Scale (SBMBDS)

The SBMBDS is usually used in aerobic training. Its range can be used to describe the effects of weight training or current condition of the patient. The scale ranges from 1 to 10 and the explanation of the intensity of exercise is given next to the scale. Following the 6MWT, assessments with the SBMBDS were performed by asking the patient to describe their level of breathlessness [21].

Statistical analysis

The data obtained in this study were analyzed using SPSS version 18.0 for Windows (SPSS Inc., Madison, WI, USA). To make comparisons between the pre- and post-test data for the 2 groups, a repeated measures analysis of variance (2×2) with a between-subjects factor was used. For comparing the differences in the pre- and post-intervention between the 2 groups, a paired t-test was conducted. Independent t-tests were performed to compare the pre- and post-test scores and the difference by time for the 2 groups. A p-value less than 0.05 was considered to indicate a statistically significant difference.

Results

Forced vital capacity (FVC)

There was a significant difference in the FVC of the exercise group before and after exercise ($p<0.05$), but no significant difference was observed in the control group. There was a significant difference in the mean difference before and after the exercise program between the 2 groups ($p<0.05$) (Table 2). FVC increased from 2.90±1.12 l to 3.99±1.19 l (an increase of 1.09±0.87 l) in the exercise group and from 2.67±0.68 l to 2.90±0.81 l (an increase of 0.23±0.44 l) in the control group.

Forced expiratory volume in 1 second (FEV1)

The FEV1 was measured before and after exercise. A significant increase was observed in the exercise group ($p<0.05$), but not in the control group. The mean difference in FEV1 before and after exercise showed a significant difference between the 2 groups ($p<0.05$) (Table 2). FEV1 increased from 2.01±0.71 l to 2.64±0.62 l (an increase of 0.63±0.57 l) in the exercise group and from 2.33±0.57 l to 2.37±0.50 l (an increase of 0.04±0.27 l) in the control group.

The ratio of forced expiratory volume in 1 second to the forced vital capacity (FEV1/FVC)

When comparing the FEV1/FVC before and after exercise, there was no significant difference for either group. There were no significant differences between the 2 groups (Table 2).

Peak expiratory flow (PEF)

There was a significant increase in the exercise group ($p<0.05$), but not in the control group, when comparing PEF before and after exercise. The mean difference in PEF before and after exercise showed a significant difference between the 2 groups ($p<0.05$) (Table 2). PEF increased from 264.00±97.86 l/s to

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Table 3. Comparison of outcome variables in exercise capacity.

		Pre	Post	Post-Pre	P
6MWT(m)	Exercise group	163.60±63.87	219.10±91.63	55.00±56.38	.012*
	Control group	177.50±78.39	191.20±77.04	8.70±9.84	.024*
				p=.028*	
SBMBDS	Exercise group	4.20±1.87	2.10±2.13	–2.10±0.99	.000*
	Control group	2.60±1.07	1.60±1.07	–0.90±0.99	.008*
				p=.015*	

p<.05.

358.00±98.607 l/s (an increase of 94.00±80.61l/s) in the exercise group and from 359.00±106.06 l/s to 367.50±106.88 l/s (an increase of 8.50±51.74 l/s) in the control group.

Six-minute walking test

There was a significant increase in the 6-min walking distance before and after exercise, in both groups ($p<0.05$). In addition, the mean difference in walking distance before and after exercise was significantly different between the 2 groups ($p<0.05$) (Table 3). The 6-min walking distance increased from 163.60±63.87 m to 219.10±91.63 m (an increase of 55.00±56.38 m) in the exercise group and from 177.50±78.39 m to 191.20±77.04 m (an increase of 8.70±9.84 m) in the control group.

Shortness of Breath Modified Borg Dyspnea Scale

A significant change was observed in the Shortness of Breath Modified Borg Dyspnea Scale (SBMBDS) scores before and after the exercise, in both groups ($p<0.05$). In addition, there was a significant difference in the mean difference of the scores before and after exercise between the 2 groups ($p<0.05$) (Table 3). SBMBDS score decreased from 4.20±1.87 to 2.10±2.13 (a decrease of –2.10±0.99) in the exercise group and from 2.60±1.07 to 1.60±1.07 (a decrease of –0.90±0.99) in the control group.

Discussion

The respiratory function of patients with stroke is worse than that of healthy individuals [22]. In addition, respiratory function and walking ability can be improved by performing various breathing exercises [4,5]. Based on these results, we hypothesized that performing breathing exercises by using an individualized respiratory muscle and an endurance device, which can strengthen both inhalation and exhalation, could influence the capacity of the respiratory muscles and endurance and improve pulmonary function. Furthermore, we hypothesized that an improvement in pulmonary function could enhance exercise capacity of patients with stroke.

In the current study, we investigated the effects of breathing exercise using an individualized respiratory device on the pulmonary function and exercise capacity in stroke patients. We found that FVC, FEV1, and PEF were significantly increased in the exercise group, but not in the control group. Additionally, 6MWT and SBMBDS were significantly improved in both groups, with a significant difference between the 2 groups. A previous study investigated the effects of breathing exercise on 40 stroke patients, divided into an exercise group with feedback breathing exercise, an exercise group combined with diaphragm resistance training and lip-pursing exercises, and a control group, 3 times a week for 4 weeks. The results showed a marked improvement in thorax size and pulmonary function in the exercise group combined with diaphragm resistance training and lip-pursing exercises than in other groups [23]. Another study has reported that training of respiratory muscles in patients with cervical spine injury increased strength of respiratory muscles, and also increased FVC and FEV1 [24]. Kim et al. reported that 12 patients with stroke, with a delayed time of central motor conduction of the diaphragm, had an FVC <80% of normal estimates; of these patients, 11 showed restrictive ventilator impairment with a relatively high reported risk [25]. Liaw et al. indicated that exercises for strengthening the respiratory muscles for 6 weeks in 10 patients with early-stage cervical spine injury resulted in an improvement of respiratory muscle strength, endurance, dyspnea, cognitive ability, FVC, and FEV1 [26]. Similarly, a study [27] examining patients with spinal injury who received breathing exercise training reported that there were statistically significant increases in FEV1/FVC and FEV1 [27]. The present study shows that FVC and FEV1 in stroke patients were improved by breathing exercise with an individualized respiratory device. According to previous studies, reduced FVC and FEV1 are related to an increased risk of various forms of cardiovascular disease, as well as a higher risk of stroke and stroke mortality in this population [5,28]. Therefore, our findings suggest that risk of stroke

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and cardiovascular disease and stroke mortality might be reduced by breathing exercises. Lower level of FEV1 is associated with an increased risk of stroke in those already at high risk and an increased recurrent stroke rate following first stroke [29]. This study shows that FEV1 was improved by breathing exercise in stroke patients and suggests that breathing exercise may help decrease stroke recurrence.

Cough is an important mechanism to protect against aspiration; cough is often impaired in stroke patients and results in higher incidence of aspiration and chest infection [30–32]. Impaired cough function is likely related to respiratory muscle weakness. Inspiratory muscle weakness leads to reduced lung volume at the beginning of a cough, and expiratory muscle weakness leads to reduced intrathoracic pressure needed to produce adequate airflow [33,34]. PEF, a measure of cough effectiveness, was found to be reduced by approximately one-third in acute and chronic stroke patients when compared with healthy elderly subjects [35]. In this study, PEF was significantly increased in the exercise group, suggesting that breathing exercise with an individualized respiratory device may improve cough effectiveness and reduce risk of stroke-associated pneumonia.

Deterioration of respiratory function is a significant issue for patients with stroke. In cases of chronic stroke injury, deterioration of cardiopulmonary capacity has an important influence on physical impairment. Deterioration of cardiopulmonary capacity and walking ability are significant factors when patients return to normal life after rehabilitation [36].This study used the 6MWT and the Shortness of Breath Modified Borg Dyspnea Scale (SBMBDS) to examine exercise capacity and there was significant improvement in 6MWT and SBMBDS in the exercise group, but not in the control group. In comparison with the differences between the pre- and post-test for the 2 groups, there was a statistically significant difference between the 2 groups. Respiratory muscle training has been reported to be associated with significant improvements in respiratory muscle strength and endurance, exercise capacity, power output, and dyspnea and suggested that respiratory muscle training might be able to improve exercise performance, symptoms, and quality of life in patient with stroke and obstructive pulmonary disease [37,38]. Respiratory muscle training, especially inspiratory muscle training, plays an important role in exercise capacity, in most of the cardiopulmonary responses to exercise, functional status, sensation of dyspnea, and quality of life in stroke patients [5]. Consistence with previous studies in stroke patients, we observed that individualized respiratory muscle training was associated with significant improvements in respiratory muscle strength, as well as with endurance and exercise capacity in stroke subjects.

The main limitation of this study is that the long-term effects of respiratory muscle training were not monitored. Therefore, long-term effect of increasing respiratory muscle training in stroke patients should be determined in a future study. Another limitation is the relatively small number of subjects.

Conclusions

The present study aimed to determine if pulmonary function and exercise capacity change after respiratory muscle and endurance training using an individualized respiratory muscle training device combined with conventional physical therapy exercise in 20 subjects with chronic stroke. The measurements involved pre- and post-test measurements of pulmonary function (FVC, FEV1, FEV1/FVC, and PEF) and exercise capacity (6MWT and SBMBDS). The results indicate that the rehabilitation training for respiratory muscles using a respiratory muscle treatment device resulted in a significant improvement in pulmonary function and exercise capacity in patients with stroke. In comparison with the control group, there was a statistically significant difference. The rehabilitation training of the respiratory muscles using an individualized respiratory muscle training device combined with conventional physical therapy exercise can improve pulmonary function and exercise capacity in patients with chronic stroke.

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